CHAPTER 9.

Legacy Effects of Emerald Ash Borer on Vegetation in Riparian Forests and Communities of Woodboring Cerambycid Beetles

Patrick Engelken

Deborah G. McCullough

INTRODUCTION

The emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae) invasion has resulted in the death of millions of ash (*Fraxinus* spp.) trees since its 2002 detection in southeastern Michigan and nearby Ontario. Previous studies assessed ash mortality and effects of EAB in urban and forested areas, but to date impacts of EAB in riparian forests have not been evaluated. These forests border rivers and streams, are often hydric, and experience periods of inundations. Riparian forest ecosystems are functionally linked to adjacent waterways. For example, riparian forests regulate transfers of energy into streams via inputs of leaf litter, provide stream structure through inputs of fallen branches and logs, and provide shade to ameliorate aquatic temperatures. Black ash (*Fraxinus nigra*) and green ash (*F. pennsylvanica*) are often abundant in riparian forests across Michigan and represent a substantial component of the riparian overstory. Impacts of EAB invasion, including mortality of overstory ash, could substantially influence terrestrial and aquatic conditions with potentially cascading secondary effects. We conducted three separate studies, described below, to assess ash mortality and effects of EAB in riparian forests.

Project 1. Legacy Effects of Emerald Ash Borer on Riparian Forest Vegetation and Structure

Methods

We identified three watersheds in southern Michigan that represented the general east-to-west temporal progression of the EAB invasion. Selected watersheds included the Clinton, Grand, and Kalamazoo River watersheds (fig. 1 in Engelken and McCullough 2020a). In each watershed, we identified a major canopy gap resulting from EAB-caused ash mortality along four first-order streams (12 sites total). In each site, we surveyed vegetation and other variables in the canopy gap and the surrounding, intact forest using a combination of fixed-radius plots and linear transects. Variables recorded included the amount of light (photosynthetically active radiation) available to vegetation in summer and winter; species and diameter at breast height (d.b.h.) of all standing live and dead trees (d.b.h. ≥10.2 cm); species and number of saplings (diameter 2.5–10 cm and height ≥0.5 m) and seedlings (diameter <2.5 cm and height ≤0.5 m); species and percentage of cover of shrubs and herbaceous plants; and species, diameter, length, and decay class of coarse woody debris (≥7.6-cm diameter). Variables were standardized per hectare for analysis. Comparisons between canopy gaps and surrounding forests and among watersheds were performed using two-factor split plot analysis of variance (ANOVA). Nonmetric multidimensional scaling ordinations, permutational analysis of variance (PERMANOVA), and indicator species analysis (ISA) were performed to compare pre-EAB overstory with the current saplings and to compare composition of vegetation in canopy gaps and forests.

Results

Prior to EAB invasion, canopy gaps were dominated largely by green ash and black ash, but >85 percent of the ash basal area was killed by EAB across all watersheds. Currently, species richness and live basal area are lower in canopy gaps than in the surrounding forests (table 1 in Engleken and others 2020). Live overstory trees were scarce in canopy gaps and consisted primarily of American elm (*Ulmus americana*), maples (*Acer* spp.), and swamp white oak (*Quercus bicolor*). Ash trees were rare in forests surrounding canopy gaps. These forests comprised oaks (*Quercus* spp.), maples, and a mix of other hardwoods such as black cherry (*Prunus serotina*) and American beech (*Fagus grandifolia*). A lower percentage of dead ash trees remained standing in southeastern sites and, not surprisingly, volume of ash coarse woody debris was higher in these sites than the areas invaded more recently. Ash saplings were abundant in canopy gaps, reflecting the species composition of overstory trees prior to EAB invasion. Saplings in forested areas adjacent to gaps were dominated by red maple (*A. rubrum*), while northern red oak (*Q. rubra*), black cherry, sugar maple (*A. saccharum*), and red maple were common in overstories. Understory vegetation in canopy gaps was dominated by dense mats of sedges (*Carex* spp.). Tree seedlings were rare and often absent in canopy gaps, presumably as a result of these sedge mats.

Discussion

In the riparian forests we surveyed, the EAB invasion has resulted in the functional loss of mature green and black ash trees. Despite the almost complete lack of a mature ash cohort, consistently high sapling densities combined with reduced EAB densities could facilitate ash persistence in post-invasion areas. If EAB densities increase, however, recruitment of ash saplings into the overstory will be limited. Continued monitoring will be important to assess the future status and dynamics of ash and other species in post-EAB riparian forests.

Project 2. Species Diversity and Assemblages of Cerambycidae in the Aftermath of the Emerald Ash Borer (Coleoptera: Buprestidae) Invasion in Riparian Forests of Southern Michigan

Methods

We conducted this project in the same field sites that were surveyed in Project 1. In each site, we deployed two Fluon®-coated cross-vane panel traps. One trap was deployed at ground level at the edge of an EAB-caused canopy gap. The other trap was suspended in the canopy of a living hardwood tree, directly above the ground trap. Each trap was baited with a lure containing racemic 3-hydroxyhexan-2-one, an aggregation pheromone known to be broadly attractive to an array of species in several tribes of the subfamily Cerambycinae, along with a pouch of ultra-high-release ethanol. Traps were deployed from May into October of 2017 and 2018. Traps were checked at 2- to 3-week intervals to retrieve captured insects, which were stored in 70-percent ethanol until identification. Two-factor ANOVA was performed on capture and species richness data to make comparisons among the three watersheds and between canopy and ground traps. Nonmetric multidimensional scaling ordinations, permutational analysis of variance (PERMANOVA), and indicator species analysis (ISA) were performed on cerambycid capture data. Vegetation and coarse woody debris recorded in sites were overlaid on the final ordination to assess site-related features that were potentially correlated with changes in communities.

Results

We captured a total of 3,645 beetles representing 65 species and five subfamilies of cerambycids. Communities of cerambycids captured in southeast sites, with the longest history of EAB invasion, differed from those collected in south-central and southwest Michigan, which were similar. Results of ISA suggested these differences were largely due to three cerambycid species that were abundant in the southeast sites. Correlation of site-related variables and beetle captures indicated cerambycid species assemblages were associated most strongly with abundance and decay stage of coarse woody debris. During both years, >90 percent of cerambycid species were captured by mid-summer, but seasonal activity differed among and within tribes. Numbers of beetles captured by canopy and ground traps were similar, but species richness was higher in canopy traps than ground traps. Additionally, communities of cerambycids captured in canopy traps differed from those in ground traps.

Discussion

Results of this study suggest that influx of ash coarse woody debris following the EAB invasion can have temporally lagged, secondary effects on communities of native cerambycids. This has resulted in changes in distribution and potentially population-level changes of several species as ash trees break down and accumulate on the forest floor. Our results also indicate that for surveys to assess nonnative cerambycid presence or native cerambycid communities, deploying traps early in the growing season and including both canopy and ground traps will yield a wide array of species.

Project 3. Riparian Forest Conditions Along Three Northern Michigan Rivers Following Emerald Ash Borer Invasion

Methods

We selected three rivers in northwest Michigan, the Betsie, Platte, and Little Manistee Rivers (fig. 1 in Engelken and McCullough 2020b), for this project. All are important spawning rivers for Great Lakes salmon and trout, provide recreational opportunities, and have substantial stretches running through public land. We used time-lapsed aerial images to identify the onset and progression of canopy gaps likely resulting from EAB-caused ash mortality along the length of the rivers. Perimeters of each gap were outlined and then analyzed using ArcMap® to quantify frequency and size of canopy gaps along each river and to estimate the proportion of the riparian buffer along each river that has been lost as a result of the EAB invasion. We then surveyed a 3–5-km stretch of each river where multiple canopy gaps occurred. We used kayaks to access three canopy gaps and three areas of intact forest between gaps along each river and then established fixed-radius plots and linear transects within the sites. Variables recorded included species and d.b.h. of standing live and dead trees (d.b.h. ≥10.2 cm); species and number of recruits (d.b.h. 2.4–10.2 cm and height >2 m), saplings (diameter <2.4 cm and height 0.5–2 m), and seedlings (diameter <2.4 cm and height ≤0.5 m); species and percentage of cover of herbaceous plants; and species, diameter, length, and decay of coarse woody debris (≥7.6-cm diameter). Variables were standardized per hectare and two-factor ANOVA was used to compare canopy gaps and intact forests.

Results

Invasion by EAB has killed >95 percent of overstory ash trees along all three rivers. Density of canopy gaps resulting from EAB-caused ash mortality ranged from 3.6 to 7.1 canopy gaps/km. Ash distribution largely followed the rivers prior to EAB invasion. Canopy gaps caused by dead ash trees now comprise 13 to 21 percent of the area in the riparian forests within 100 m of the banks of all three rivers (table 3.1 in Engelken and McCullough 2020b). These gaps were originally dominated by a mixture of green and black ash, which comprised 46 to 71 percent of the total basal area prior to EAB invasion. Ash trees were rare in intact forests, comprising <10 percent of basal area. Overstory composition of forests surrounding canopy gaps varied among rivers but were generally dominated by maples mixed with bigtooth aspen (*Populus grandidentata*), swamp white oak, eastern white pine (*Pinus strobus*), or eastern hemlock (*Tsuga canadensis*). Advance regeneration was abundant in gaps, and green ash accounted for >40 percent of recruits and >60 percent of saplings along all rivers. Black ash regeneration, however, was rare or nonexistent. Similar to observations in southern Michigan, sedge mats dominated canopy gap understories and few tree seedlings occurred in gaps.

Discussion

Our results indicate that EAB-caused mortality has created substantial and frequent canopy gaps in riparian forests bordering the three rivers in northwestern Michigan, potentially threatening stability of riparian buffers and altering aquatic conditions. As in southern Michigan, green ash saplings and recruits are abundant in canopy gaps, but whether they will persist and eventually move into the overstory remains unknown. The absence of new seedlings in canopy gaps indicates that if saplings and recruits do not reach maturity, these canopy gaps may persist over time. The lack of black ash regeneration is particularly troubling. Continued monitoring to quantify long-term dynamics of tree species and effects of ash mortality on aquatic conditions of these and other affected rivers will be important.

For more information, contact: Patrick Engelken engelke2@msu.edu; Deborah G. McCullough, mccullo6@msu.edu.

LITERATURE CITED

Engelken, P.J.; Benbow, M.E.; McCullough, D.G. 2020. Legacy effects of emerald ash borer on riparian forest vegetation and structure. Forest Ecology and Management. 457: 117684. https://doi.org/10.1016/j.foreco.2019.117684.

Engelken, P.J.; McCullough, D.G. 2020a. Species diversity and assemblages of Cerambycidae in the aftermath of the emerald ash borer (Coleoptera: Buprestidae) invasion in riparian forests of southern Michigan. Environmental Entomology. 49(2): 391–404. https://doi.org/10.1093/ee/nvaa013.

Engelken, P.J.; McCullough, D.G. 2020b. Riparian forest conditions along three northern Michigan rivers following emerald ash borer invasion. Canadian Journal of Forest Research. 50(8): 800–810. https://doi.org/10.1139/cjfr-2019-0387.